Answers to Questions: Arie Bodek and Jiyeon Han

Introduction: We have refined our method and added an additional tuning using the Z mass distribution. The philosophy is as follows.

Although shift Z mass peak is least sensitive to systematic from efficiencies or modeling the Z PT, the two legs are correlated. So the shift in the Z mass (if we have no corrections) can come from either leg. This is why we use the mean <1/PT> to obtain a first correction that removes all the biases between positive and negative muons, and has no bias in eta and phi. However, since the MC does not model the efficiencies perfectly (e.g. muon PT dependence of efficiencies as a function of eta phi, we are left with a random systematic error (which has no bias) that lead to an spread in the mean Z mass (DM). This additional systematic is only in the data, it does not show up in the MC, since the efficiencies in the MC are known.

We decided to remove that systematic error as follows. We apply further tuning by adjusting the corrections to the muon momentum in eta such that to remove the spread in the mean Z mass. If we take a given eta/phi bin, and calculate the mean Z mass, any shift from the 2nd leg averages to zero (since we have removed all biases using the <1/PT>.) Therefore, for each eta/phi bin, the shift in the Z mean mass originates only from one leg, and can be used to further tune the momentum scale correction for a given eta/phi bin.

Once we apply this additional tuning of the momentum scale coefficients, the spread in DM for the data and MC are the same, and the spread in the DM is very small.

This final tuning removes all other systematic errors that only affect the <1/PT> distribution, but not the mean mass. For example, any systematic error from modeling the Z PT is now gone, since the Z PT distribution does not affect the average Z mass.

- What exactly goes to the efficiency corrections? Id+iso scale factors? Trigger efficiency (or scale factors)?

The efficiency contains ID and isolation cut (fractional iso < 0.15) and this efficiency scale factor goes into MC.

For the trigger efficiency, we estimated the trigger efficiency as a function of eta in data and this trigger efficiency is applied into MC using event weighting. The event weighting for the trigger efficiency of events = teff(eta1)*teff(eta2) where teff is the trigger efficiency of DoubleMu trigger (HLT_Mu17_Mu8) for one muon object.

- Which trigger do you use, is it IsoMu24?

We use DoubleMu trigger which is HLT_Mu17_Mu8.

- Do you apply the efficiency corrections also to 2011A data?

Yes, we applied the efficiency correction for 2011A, too.

- What is the granularity of the efficiency corrections? We suppose 8 eta bins, but please confirm (actually it might make sense to do it 8x8, means in phi as well).

We measured the efficiency as a function of eta only using 48 bins from -2.4 to 2.4 (eta bin size = 0.1). The Phi dependence has been averaged out.

Now that we are using the DM shift to further tune the muon scale corrections, we become independent of the detailed phi and PT dependence of efficiencies and are not sensitive to them any more. (the 2nd leg averages to zero in our DM tuning).

- From where do you take the efficiency corrections?

We measured the efficiency corrections using T&P method using Z events in the mass range of 60 < M < 120 GeV.

The background subtraction for the efficiency was done using the simulation even though the background level is small.

The total efficiency for 2011A in data for one muon is 0.963+-0.001, the efficiency for 2011B is 0.947+-0.001, vs. MC is 0.965 +- 0.001.

The efficiency as a function of eta is posted at :

2011A : http://www-cdf.fnal.gov/~jyhan/cms_study/momcor/muon_id_eff_2011A.eps

2011B : http://www-cdf.fnal.gov/~jyhan/cms_study/momcor/muon_id_eff_2011B.eps

Trigger efficiency in pt>20 for 2011A : 0.9595 +- 0.0006

Trigger efficiency in pt>20 for 2011B : 0.9554 +- 0.0006

The trigger efficiency as a function of eta is posted at :

2011A : http://www-cdf.fnal.gov/~jyhan/cms_study/momcor/trigeff_2011A.eps

2011B : http://www-cdf.fnal.gov/~jyhan/cms_study/momcor/trigeff_2011B.eps

- What is your mass cut? Did you check how your results depend on the mass cut and on the pt cut?

We used the mass range of 60 < M < 120 GeV.

Our pt cut is pt > 20 GeV, but we got the average of pt, <1/pt>, from the range of pt>25 GeV to remove tail of 1/pt distribution.

After getting the correction, we tested how much the correction works for high mass or low mass, and also the different pt range.

(J.C Youn also confirmed that the correction works well for the different mass range and also the different pt range.)

Since the <1/PT> correction is iterative, it is independent of the range or pt cut (the cut is imposed on the corrected PT. In addition, with the additional fine tuning using DM, the procedure is certainly independent of the cut on the <1/PT> distributions, which only yield the first order momentum scale corrections

- How do you get Acor from dM? Is it something similar to slide 10?

For the presentation was sent to you, we got Acor from the equation :
Acor = 1/(1 + dM/M)
And iterated till we got dM close to zero.

However, correction should be "Acor = 1/(1 + 2.0*dM/M)" because dp/p corresponds to 2.0*dM/M.

Therefore, we repeated the tuning of the muon scale corrections using "Acor = 1/(1 + 2.0*dM/M)".
In this case, the iteration procedure converged much faster, but the RMS of the Gaussian shape in the final dM/M is the same (0.06%) with the previous approach.

- ***We understood that applying the extra step correcting iteratively for dM/M differences you manage to get the dM/M RMS from 0.2% to 0.06%. This means that the bin-by-bin systematic uncertainty on dpt/pt is 0.4% if you do not apply the extra step or 0.12%. if you apply the extra step. How do you get to the conclusion that former is 0.12% and latter is 0.06%?***

One sentence for the conclusion was not correct.
The correct conclusion is that with the extra step we have 0.06 % random systematic error on dM/M which is equivalent to 0.12% additional random uncertainty for dp/p. The bias is zero.

- Still it remains to understand the systematic uncertainty on the average correction. In principle, one could obtain it from the mean of the dM/M plots even though it would be better to just look at the difference between the average bias before and after the dM/M step. Anyway, since the dM/M deviations are quite symmetric it looks like this systematic effect is on the average very small (<0.01%).

The mean of dM/M plot is already zero before the additional correction using the mass.

It means that our standard correction before dM/M step correction (additional correction) removes the average bias already.

- ***You claim that the origin of the "random systematics" is in efficiencies. This is still not completely obvious. If it was, we could call it "efficiency systematics".***

We indeed confirmed that for the largest DM shifts, the 1/PT distribution in the data were somewhat distorted with respect to MC, and for the smallest DM shift, the shapes of the <1/PT> distributions for data and MC were in very good agreement.

Since the 2011B data set shows the largest effect, we used 2011B data set for this test.

<1/pt> value is obtained for 1/pt<0.04, so we plotted 1/pt distribution up to 1/pt=0.04.

in the comparison to the MC we the normalized the 1/PT distributions by the total number of Z events in data with the mass range, 60 < M < 120 GeV.

The largest dM shift (mu-, the first eta bin) : black-data and blue-MC : http://www-cdf.fnal.gov/~jyhan/cms_study/momcor/mum_rpt_dis_0.eps

The smallest dM case (mu+, the last eta bin) : black-data and blue-MC : http://www-cdf.fnal.gov/~jyhan/cms_study/momcor/mup_rpt_dis_7.eps

The worst case shows discrepancy between data and MC, but the best case shows good agreement in 1/pt spectrum shape between data and MC.

- The slide 16 deals with the spectrum correction. For us, it demonstrates only that Madgraph describes data much better then Powheg. This you could probably see if you divide the black and blue points, which should correspond to ratio data to Madgraph. We disagree that the systematic error using Madgraph would be

overestimated (actually, since the correction is applied always using the data/MC ratio, the differences should be very small). The main point here is actually the precision with which we know the pT correction factor. It looks like above certain pT the uncertainty on the pt correction factor is larger then the 10% you assign. It would make more sense to use the uncertainty on the correction factor to study the related systematic.

The further tuning with DM removes any sensitivity to the Z PT distribution.

- Trying to summarize the total uncertainty on the average correction one could use the table on slide 9 of your previous presentation https://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=188595
The effects on d(1/pt)/(1/pt) = dpt/pt are proportional to: dG, <pT>*dDm, <pT>*dDa. For data (for each 2011A or 2011B), taking <pt>~50GeV this results in:
. for Dm: dpt/pt ~ 0.02%(stat) +- 0.4%(syst)
. for Da: dpt/pt ~ 0.02%(stat) +- 0.02%(syst)
. for G: dpt/pt ~ 0.01%(stat) +- 0.08%(syst)
Here, the striking effect is systematics coming from Dm! How did you obtain this systematics?

For the overall systematics, we got the corrections, Dm, Da, and G factor changing the conditions like 30% change of background,
10% shift of Z Pt correction, change of detector resolution functions.
And the shift from the standard value for Dm, Da, and G is assigned as the systematic uncertainty.
The systematic uncertainty from Z Pt correction gives the biggest shift in Dm correction factor.
Dm is defined as (C(mu+) + C(mu-))/2.0 where C = <1/pt>(gen) - <1/pt>(rec) and
Da is defined as (C(mu+) - C(mu-))/2.0 .
The change of Z Pt correction shifts C for mu+ and mu- systematically,

but this systematic shift is cancelled in Da because
it is difference of C(mu+) and C(mu-).
However, this shift gets double in Dm because it is sum of C(mu+) and C(mu-).
That's why the systematic uncertainty for Dm is much bigger compared to Da or G factor.

However, if we apply the additional correction using Z mass, it removes the sensitivity of Z Pt correction.
==> We need to redo this systematic and only determine it AFTER the DM correction.